THE EFFICACY OF NONAKA’S KNOWLEDGE CREATION SPIRAL IN ADVANCING TEACHERS’ TPACK

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This paper reports the use of Nonaka’s knowledge creation spiral as a design strategy for developing teacher TPACK. While it is evident in the literature the importance of TPACK for technology integration, it is less obvious how to develop TPACK in teachers. Designed using the case study approach, a total of 28 teachers participated in our professional development programme that required them develop shared knowledgeable objects as a knowledge creating community. Preliminary findings indicated a growth of TPACK evidenced by (1) a deep understanding of student learning difficulty, (2) a tight technology and pedagogy coupling in the lesson design, and (3) appropriate design of TPACK scaffolds. We discuss our early assertions of Nonaka’s knowledge creation spiral as conclusion of this paper.

Keywords: Knowledge creation, TPACK, learning design, teacher professional development.

INTRODUCTION

The view of knowledge creation as a metaphor of learning (Paavola, Lipponen & Hakkarainen, 2004) has gained prominence in the teaching and learning community in recent years. Recent studies have contributed to the theory of knowledge creation (e.g. Tee & Lee, 2013) or, produced empirical results that supported learning as knowledge creation (e.g. Hong & Sullivan, 2009).

This paper aims to report on the efficacy of the use of Nonaka’s knowlede creation spiral (Nonaka & Takeuchi, 1995), namely socialization, externalization, combination and internalization (SECI), as the basis of ba (a Japanese word that means a dynamic shared context) in developing teachers’ TPACK (technological, pedagogical, content knowledge). Many empirical studies have found that teachers’ use of technology in teaching and learning largely premised on information transmision and regurgitation (Lim & Chai, 2008; Ward & Parr, 2010). Findings indicated that the lack of meaningful learning experiences with technology is in part due to teachers having limited TPACK (Mishra & Koehler, 2006; Koehler, Mishra & Yahya, 2007). According to Nonaka, Toyama and Byosiere (2001), the SECI spiral is an enabling and dynamic process that facilitates rich and constructive conversations around a shared object. Hence, it is envisaged that the SECI spiral, when applied in the context of developing teachers’ TPACK, enhances teachers’ capacity to design meaningful technology-enabled learning experiences.

In this paper, we first examine some conceptual issues surrounding knowledge creation, and how it is a useful design strategy for developing teachers’ TPACK. Then we explain the
research design of this project in which we present an outline of how the SECI spiral is applied in our professional development programme. Thereafter, we present our preliminary findings of (1) a deep understanding of difficulties students face, (2) a tight technology and pedagogy coupling, and (3) appropriate TPACK scaffolds. These themes suggest that there is a deepening of teachers’ TPACK. As a result of this promising findings, we discuss our early assertions of the efficacy of Nonaka’s SECI spiral for development of teacher TPACK as conclusion of this paper.

KNOWLEDGE CREATION AS A DESIGN STRATEGY TO DEVELOP TPACK

The knowledge creation metaphor of learning is an epistemological lens positioned for an innovation-driven knowledge-based society. Learning in this perspective is driven by inquiry where knowledge is iteratively developed and enhanced. More importantly, the knowledge-creation approach emphasizes in the making of “shared knowledgeable objects” (Hakkarainen, 2008). These shared objects mediate the exchange between the individual and the social in which they provide the impetus for collective actions, and concomitantly give meaning to the participation of the individuals. Moreover, these shared objects do not remain static but they evolve over time. Hence, the boundaries of process and product are blurred as the shared objects which embody innovation transform over time.

The value of the knowledge creation metaphor for learning is appreciated when it is regarded in tandem with the acquisition and the participation metaphors. In a well-cited paper, Sfard (1998) described the acquisition metaphor to that of information transmission to fill a human mind. Learning in this perspective entails individual information processing in order to decipher the knowledge structures, mostly in the form of schematas. On the other hand, the participation metaphor is about growing in the likeness of a community. Learning in this perspective is about appropriation of the norms, discourse and practices of the community. According to Paavola, Lipponen & Hakkarainen (2004), the knowledge creation metaphor bridges the dichotomy of the acquisition and the participation metaphor. It does so by having knowledge at the forefront of the learning process, while recognizing the importance of the situated nature of social interactions.

This knowledge creation view of learning seems appropriate for the development of teachers’ TPACK. TPACK is a type of knowledge that enables the use of technology to support learning effectively (Mishra & Koehler, 2006). Effective learning in this case is not merely about regurgitating information, but that the outcomes of Meaningful Learning is achieved (Jonassen, Howland, Marra & Crismond, 2008). Meaningful Learning, according to Jonassen, Howland, Marra & Crismond (2008), is about learning with technology where learners construct knowledge that made sense to them. A recent study has found that the lesson plans teachers developed after a 12-week ICT course failed to engage students in divergent thinking and knowledge building (Koh, 2013). Findings revealed that student learning needs is ill-structured in nature. Without careful planning and analysis, the use of technological tools coupled with pedagogy may not adequately or effectively address the problems students face. Thus, technology integration is not a standardized prescription that can be applied unproblematically all the time. To be effective, teachers require sophisticated TPACK to develop an appropriate technology-enabled solution to address student learning needs.

While it is apparent that teachers need TPACK, it is less clear how to develop TPACK in them. To develop good teaching (which includes TPACK), it has been postulated that teachers need to participate in iterative design cycles (Laurillard, 2012). Specifically, they
need to iteratively make sense of their prior experiences of what had worked or failed, what technological tools are available and how they might be used, what diverse characteristics learners have, and so on. Because of these diverse knowledge bases, it is therefore not surprising for such a process of learning to involve different entities across different levels and organizations. In short, given the landscape of technology integration and the attributes of the knowledge creation view of learning, the latter lends itself a useful design strategy to develop teachers’ TPACK.

At this point, it is appropriate to note that there are several models of innovative knowledge communities in the literature (see Paavola, Lipponen & Hakkarainen, 2004 for a comparative analysis of three models). While we do not intend to present another comparative analysis here, we state the advantage Nonaka’s SECI spiral bears on our professional development programme (a detailed outline of the professional development programme is presented in the methodology section). The SECI spiral comprizes four stages, namely socialization, externalization, combination and internalization. Socialization is a process of sharing context-specific experiences. This is the stage where common ground among members is established and members are motivated in creating the shared knowledgable objects. Externalization is the phase where tacit knowledge is deliberately overtly represented to other members for meaning making. Combination builds on the externalization phase where new ideas are formed and tested. Internalization is the process of embodying new knowledge and practice through action and reflection.

With respect to our professional development programme, Nonaka’s SECI spiral is preferred for several reasons. First, the SECI spiral does not only outline the process of creating innovations, it makes overt how knowledge is converted from stage to stage. Such an emphasis on knowledge conversion helps teachers to visualize in concrete ways how their ideas are transformed from stage to stage. Next, the SECI spiral, being a four-stage model, renders it flexible to be practiced in iterations. Teachers worry less about where they are in the knowledge creation process, and the tendency for them to be lost in the interactions is reduced.

In summary, in this section, we examined key conceptual issues surrounding the knowledge creation metaphor and how the construct enables the development of teachers’ TPACK. We further explained why Nonaka’s knowledge creation spiral is preferred in our teacher professional development programme.

RESEARCH DESIGN

Case Study Design

The first step we took in this study was to draft a research design. We limited our study to understand the efficacy of the knowledge creation approach in our teacher professional development programme. In this light, we did not conduct ethnographic observations of teachers’ day-to-day activities which may include other learning activities. Instead, we focused on the interactions that occurred during the professional development programme, the shared knowledgable objects in the form of the lesson plans produced, and observations of the lesson(s) that was implemented (where possible). This bounding of the study was consistent with the exploratory qualitative case study design where causes and models of conditions were not readily available (Yin, 2011). We also bounded this study by time (two years) and by a single case (the community of teachers selected from six participating schools).
Participants

The professional development programme is a zonal training planned for about 30 teachers from six schools. As the programme focuses on Math learning with technology in elementary schools, the selection criteria for the schools are: (1) schools have been using technology in their teaching and learning, (2) teachers are comfortable with engaging in inquiry with teachers from other schools, and (3) teachers are currently teaching Math or are involved in the elementary Math curriculum. Through the zonal ICT committee, the six schools were identified through which the leaders of the respective schools further selected four to five teachers to participate in the programme. A total of 28 teacher participants were selected at the end of the selection process.

Intervention

The goals the professional development programme sets out to achieve are:

1. Deepen digital learning through a knowledge-creating community
2. Increase teacher capacity for designing digital learning

Each school was free to decide on a technology-enabled lesson of their choice. The guiding principles given to them were to identify a learning problem that is prevalent in many students, or to select a conceptually difficulty Math topic that students struggle with. Once the topic of inquiry was decided, teachers were tasked to design a technology-enabled lesson, implement it, and briefly evaluate its effectiveness for student learning. This process was to be done in tandem with the contributions from the six-school collectively. Hence, the lesson developed by each school is a shared knowledgeable object owned by everyone in the community.

The programme (see Table 1) comprised five meetings conducted over nine months. In each meeting, the round robin approach was taken for teachers of each school to share on their topic of inquiry. During this time, they explained their contextual-bound conditions, constrains, dilemmas, and opportunities. In return, the teachers from other schools participated by sharing their relevant experience and reflections. Throughout this period, teachers encouraged to question one another in order to understand each other’s point-of-view. They were also encouraged to probe and make overt the concepts or knowledge that were being discussed. The researchers facilitated all five sessions.
Table 1

Professional Development Programme for Knowledge-Creating Community in Elementary Math

<table>
<thead>
<tr>
<th>Session</th>
<th>Process</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Socialization</td>
<td>• Understand digital learning.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Question and analyze student learning issues in Math.</td>
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<tr>
<td></td>
<td></td>
<td>• OUTCOME: Tease out/pin point the critical factor that will address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>learning issue e.g. visualization for understanding cuboid</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Externalization and</td>
<td>• Share and model a new pedagogical-backed solution with ICT</td>
</tr>
<tr>
<td></td>
<td>Combination</td>
<td>• OUTCOME: Identify possible ICT solutions that are grounded on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pedagogical principles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Examine new model by experimentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• OUTCOME: Use rapid prototype approach to implement, analyze</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and fine-tune ICT-based solution</td>
</tr>
<tr>
<td>5</td>
<td>Internalization</td>
<td>• Reflect and distill key pedagogical principles of the innovative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICT-based pedagogical practice.</td>
</tr>
</tbody>
</table>

Data Collection and Analysis

The data that we collected included the shared knowledgable objects in the form of lesson plans and resources, the meeting talk, and lesson observations (if any). This study employed the assumptions of a context-dependent inquiry, and an inductive data analysis design. We planned to perform content analysis for all the shared knowledgeable objects coded according to the rubrics of TPACK (Koh, 2013). This will be done on a individual school basis, and thereafter the codes will be combined across all schools for emerging themes. As for the meeting talk, all of them will be transcribed and the transcripts will be analyzed and coded according to how teachers’ TPACK evolved over time. As the project has just ended, in the section below, we present our preliminary findings of one of the schools, Cornerstone School (a pseudo name). The content analysis of the shared objects (lesson plans, lesson resources & teacher reflections) suggests that SECI spiral design approach facilitated the deepening of TPACK in teachers.

FINDINGS

In this section, we describe the common themes we observed in the content analysis of the various data, namely the lesson plans, observation of the lesson implementation, and the teachers’ reflections. Our observations were derived by constantly comparing (Glaser, 1965) the codes across the different shared objects. For the purposes of this paper, we used the shared knowledgable objects of Cornerstone School as examples to illustrate the themes we found.
Deep Understanding of Difficulties Students Face

The topic of inquiry the teachers of Cornerstone School have chosen is area of composite figure. This is a topic that requires students to first decipher the basic shapes that a composite figure is made up. Then students proceed to apply mathematical formulas for problem solving. When the teachers first discussed about this topic in the socialization phase, their discourse were confined to “students cannot see” the basic shapes that makes up a composite figure. However, when probed by the community to unpack “cannot see,” their discourse and therein their thinking began to shift. Their reflections indicated the shift to a more robust rationalization grounded in cognitive science in the form of spatial visualization and the use of mathematical heuristics for problem solving.

Our team has chosen using spatial visualization skills to solve problems on area and perimeter... Generally, pupils are weak in non-routine questions, especially those that require visualization or how shapes interact with one another in terms of rotating the shapes. They have a fixed set of thinking when solving problems and lack the ability to think out of the box or have other alternative solutions.

Building on this understanding, they have designed a lesson that draws on the pedagogy of productive failure (Kapur 2008, 2010). To do that, they have chosen a question (see Figure 1) that calls for a high level of spatial visualization for students to work through the ‘failing experience’ so as to promote thinking out of the box. Moreover, the pedagogy chosen to carry out this lesson is student-centric in nature where students were to discuss their hypothesis and assumptions as part of their problem solving process.

We decided to incorporate Productive Case Failure in our redesign of our lesson. Presenting the students with a scenario in which they are likely to fail was part of our redesign. The new lesson also shifted the focus from Direct Instruction (from the teacher) to a more student centric approach, involving more discovery and inquiry based learning.

![Figure 1](image1.png)

*Figure 1. Question on area of composite figure*  
Source: A-Star Maths Problem - Mensuration (Second Edition)

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1 In the case of Figure 1, through visualization, students are to decipher that 2 lengths is equal to 3 breadths.
Good Technology and Pedagogy Coupling

The technology that the teachers have used is an iPad app *Explain Everything™* (see Figure 2). It is an app that records on-screen inscriptions as well as audio. The affordance of the app facilitated the representation of cognition where student’s mathematical thinking was clearly shown in both visual and audio means. When used in tandem with student discussion, the videos facilitated student exchange by showing the mathematical conception clearly.

The choice of the app revealed the teachers’ conception of TPK (technological pedagogical knowledge). They were not only able to relate the affordance of the app (recording of audio and on-screen inscription) as a means of representing cognition, they were able to associate the affordance with pedagogy, that is collaborative learning.

The main other change in the lesson was also the shift from PCK to TPACK. The use of technology allows capturing of the mathematical discourse, using multiple representations and seeing how the shapes interact. In our lesson, we wanted to make use of ICT to help us capture the mathematical discourse of the students and encourage visible thinking in the students, as well as surface misconceptions of the students…

*Figure 2. Student problem solving on iPad app* *Explain Everything*
Appropriate Design of TPACK Scaffolds

Another evidence of teacher TPACK is in the design of scaffolding. The enactment of TPK was not done in a random manner, depending on students’ ability. Scaffolding structure in the form of mathematical discourse (see Figure 3) was set in place to help facilitate student exchange. Specifically, the discourse was designed to elicit student mathematical thinking.

…in using the Explain Everything App, pupils are encouraged to justify their reasons when coming out with the solutions. They have to give reasons why they think that the length or breadth of a rectangle is of a certain measurement. Steps on how to solve the problem were also recorded by the pupils. Furthermore, pupils also used certain specified structures to justify their reasoning, show disagreement and seeking clarifications…

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| **Explaining Ideas** | The reason I do this is because __________________________. |
| **Asking for Clarifications** | I understood the part that you said about, but I didn’t understand _______________. |
| Can you explain that again? |
| Can you show me how arrive at this step? |
| **Disagreeing Politely** | I agree with you because _______________. I disagree with you about _______________. Could both of us be right? |
| That’s an interesting idea. I disagree with you about _______________. |
| Could you tell me why you think ________________? |

*Figure 3. Scaffolds as mathematical discourse designed to promote mathematical thinking.*

**DISCUSSION AND CONCLUSION**

In the above illustrative example, we have shown evidences of teachers TPACK in three different aspects, namely (1) a deeper understanding of the challenges students face, (2) technology and pedagogy coupling, and (3) appropriate TPACK scaffolds. Developing teachers’ TPACK takes more than just attending a course. Because of the diverse knowledge bases that TPACK draws on, the interaction across different entities across different levels facilitated that development of TPACK. In the design of our professional development programme, there was diverse insights and perspectives from the teacher participants as well as from the researchers. Furthermore, the technological experience different parties brought into the discussion enriched the sense making of what technology can do to support teaching and learning.
The value of Nonaka’s SECI spiral in making knowledge overt has allowed teachers to make overt their tacit understanding of how teaching and learning in Math occurs in the classroom. The ba context designed through the SECI conditions has helped to manage teachers’ expectations during the programme. As opposed to the typical training where teachers received from experts, teachers participated with the goal of not only learning from one another but also learning with one another. In addition, through the phases of externalization and combination, teachers learned to focus on the shared knowledgeable objects where they take questions and suggestions professionally. In so doing, teachers considered the various perspectives of teachers from the group and the wide range of conditions for learning such as scaffolding mathematical discourse which led to a richer and coherent lesson design.

While the above findings indicated a deepening of teacher TPACK among the teacher participants. It is still too early to assert the efficacy of Nonaka’s knowledge creation spiral as a design strategy to develop teachers’ TPACK. Arising from this promising initial analysis, we will continue to work through the rest of the data through which we hope to pinpoint the specifics on how the SECI spiral promoted shifts in discourse and growth in knowledge. We hope that further insights into how teacher’s TPACK can be developed can be reported in related educational journals.

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